PB89-142434

Best Demonstrated Available Technology (BDAT): Background Document for K037

(U.S.) Environmental Protection Agency
Washington, DC

Aug 88

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/530-SW-88-031I	2.	3. Recipient's Accession No. PB89 142434/AS

4. Title and Subtitle
BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) BACKGROUND DOCUMENT FOR K037 (FINAL)

5. Report Date
AUGUST 1988

6.

7. Author(s)

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8. Performing Organization Rept. No

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered
BACK. DOCU: 8/88

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K037 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization and treatment information that serves as a basis for determining whether variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the wastes upon which the BDAT treatment standards are based.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement RELEASE UNLIMITED	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 139
	20. Security Class (This Page) UNCLASSIFIED	22. Price / MF PC$ 21.95/ 6.95

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)

EPA/530-SW-88-031I

PB89-142434

FINAL

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K037

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August 1988

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U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

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EXECUTIVE SUMMARY

BDAT Treatment Standards for K037

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act as enacted by the Hazardous and Solid Waste Amendments on November 8, 1984, the Environmental Protection Agency (EPA) is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K037. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. The effective date of these treatment standards is August 8, 1988.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K037 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization and treatment information that serves as a basis for determining whether variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the wastes upon which the BDAT treatment standards are based.

The introductory section of this document (Section 1), which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information: the number and locations of facilities affected by the land disposal restrictions for K037 waste, the waste-generating process, characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

Waste code K037 is listed as "wastewater treatment sludge from the production of disulfoton." The Agency is aware of only one facility that generates waste identified as K037.

The Agency is regulating two organic constituents in the wastewater and nonwastewater forms of K037. (For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Waste not meeting this definition must comply with the treatment standards for nonwastewaters.) The treatment standards for the organic constituents in both wastewater and nonwastewater forms of K037 are based on performance data from rotary kiln incineration.

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* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and filterable solids." Specifically, total suspended solids is measured by method 209C (Total Suspended Solids Dried at 103-105°C) in Standard Methods for the Examination of Water and Wastewater, Sixteenth Editon.

The following table presents the specific BDAT treatment standards for K037 wastewater and nonwastewater. The treatment standards for both wastewater and nonwastewater reflect the total constituent concentration. The units for the total constituent concentration are mg/kg (parts per million on a weight-by-weight basis) for the nonwastewater and mg/l (parts per million on a weight-by-volume basis) for wastewater. If the concentrations of the regulated constituents in K037, as generated, are lower than or equal to the BDAT treatment standards, then treatment is not necessary as a prerequisite to land disposal.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix B of this background document.

BDAT Treatment Standards for K037

Constituent	Maximum for any single grab sample		
	Nonwastewater		Wastewater
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
Volatile Organics			
Toluene	28	NA	0.028
Organophosphorous Insecticides			
Disulfoton	0.1	NA	0.003

NA = Not applicable.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters. Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and

5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.

2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:

    - Number and types of constituents treated;
    - Performance (concentration of the constituents in the treatment residuals); and
    - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BOAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4 Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104 28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be presen..

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.

3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.

2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.

3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.

4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards, then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the appropriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the requirements of 40 CFR Part 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.

2. A statement of the petitioner's interest in the proposed action.

3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.

4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.

5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)

6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)

7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.

8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.
10. A description of the methodologies and equipment used to obtain representative samples.
11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.
12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

The purpose of this section is to provide a complete characterization of the K037 listed waste by describing the industry that generates the waste, the process that generates the waste, and the data that characterize the waste. According to 40 CFR Part 261.32 (hazardous wastes from specific sources), the waste identified as K037 is specifically generated by the manufacturers of disulfoton and is listed as follows:

K037 - Wastewater treatment sludge from the production of disulfoton.

2.1 Industry Affected and Process Description

Only one facility in the United States is known to produce disulfoton. It is located in EPA Region VII, in the State of Missouri.

The disulfoton production process consists of three basic steps: (1) the formation of diethyl salt (DES), (2) the formation of chlorothio alcohol (CTA), and (3) the reaction of DES and CTA to form disulfoton. A flow diagram for the disulfoton production process is presented in Figure 2-1.

In the first step of the process, diethyl phosphorodithioic acid is formed in the DES unit from the reaction of P_2S_5 and ethanol in toluene. The major side product of this reaction is the 0,0,0-triethylester of the phosphorodithioic acid. The diethyl phosphorodithioic acid is next reacted in the same vessel with caustic

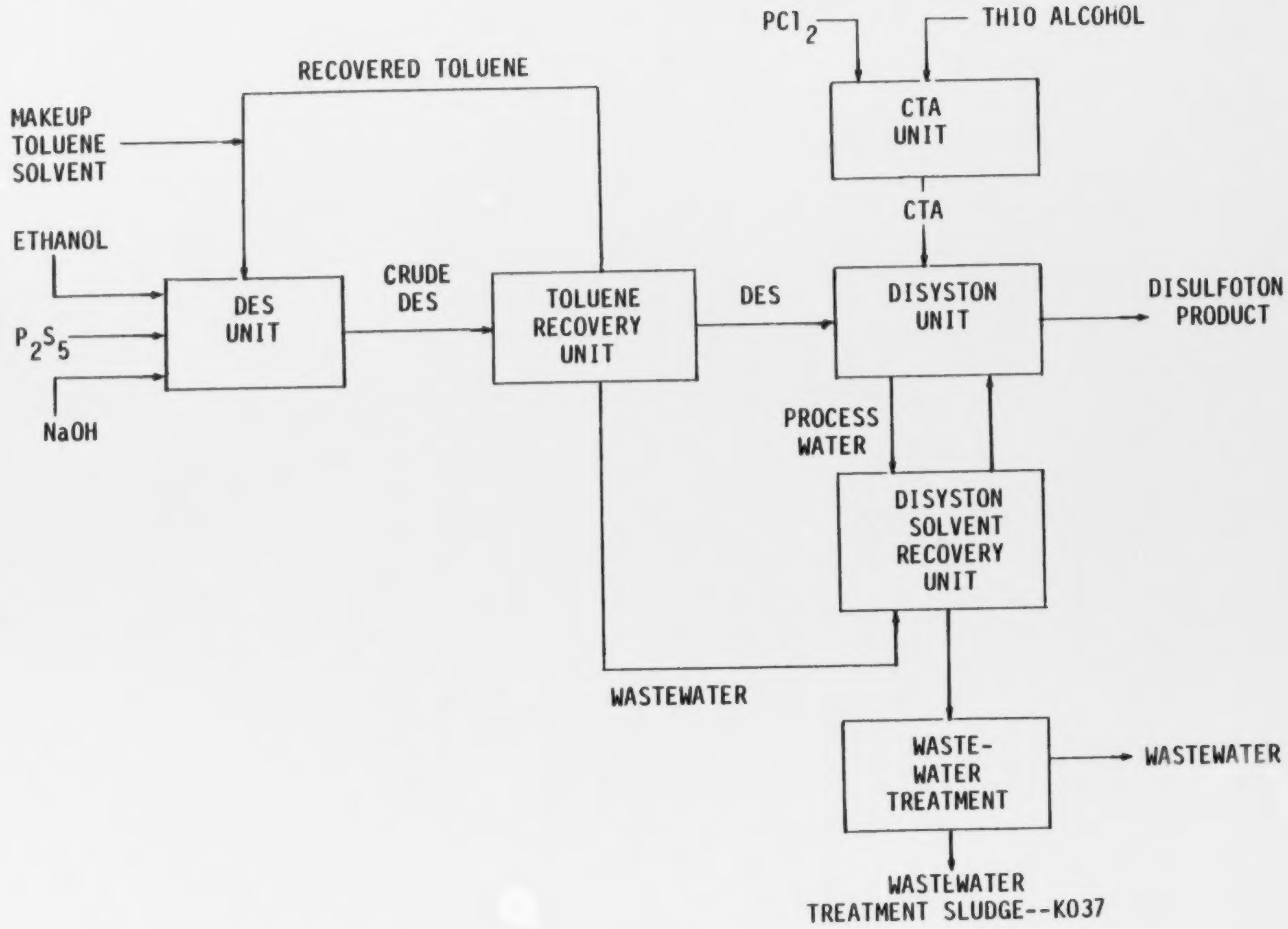
PCl_2
THIO ALCOHOL
CTA UNIT
CTA
RECOVERED TOLUENE
MAKEUP TOLUENE SOLVENT
ETHANOL
P_2S_5
NaOH
DES UNIT
CRUDE DES
TOLUENE RECOVERY UNIT
DES
DISYSTON UNIT
DISULFOTON PRODUCT
PROCESS WATER
DISYSTON SOLVENT RECOVERY UNIT
WASTEWATER
WASTE-WATER TREATMENT
WASTEWATER
WASTEWATER TREATMENT SLUDGE--K037

Figure 2-1 Production and Waste Schematic for Disulfoton

soda to form DES. The overall reaction for both subreactions is as follows:

$$\underset{\text{}}{P_2S_5} + \underset{\text{Ethanol}}{4C_2H_5OH} + 2NaOH \xrightarrow{\text{Toluene}} \underset{\text{DES}}{2(C_2H_5O)_2P(S)SNa} + H_2S + 2H_2O.$$

The DES is then separated from the reaction mix, which is sent to a toluene recovery unit. The recovered toluene is recycled back to the DES unit.

The second step of the disulfoton production process takes place in the CTA unit, where PCl_3 and thio-alcohol are reacted to form CTA as follows:

$$PCl_3 + 3HOC_2H_4\text{-}S\text{-}C_2H_5 \text{ ---> } 3ClC_2H_4\text{-}S\text{-}C_2H_5 + H_3PO_3.$$

In the final step of the process, DES and CTA are reacted in the disyston unit to form disulfoton and sodium chloride:

$$(C_2H_5O)_2P(S)SNa + ClC_2H_4\text{-}S\text{-}C_2H_5 \text{ ---> } (C_2H_5O)_2P(S)\text{-}S\text{-}C_2H_4\text{-}S\text{-}C_2H_5 + NaCl.$$

Process water from the disyston unit is sent, along with wastewater from the toluene recovery unit, to the disyston solvent recovery unit, where disulfoton is recovered and recycled to the disyston unit. Wastewater from the disyston solvent recovery unit is circulated to wastewater treatment. The sludges generated from wastewater treatment are the waste stream K037.

2.2 Waste Characterization

This section includes all waste characterization data available to the Agency for K037 waste. The approximate percent concentrations of the major constituents composing K037 waste are listed in Table 2-1. The percent concentration in the waste was determined from engineering judgment based on analytical data and plant information. The ranges of BDAT list constituents present in the waste and all other available parameters affecting treatment selection data are presented in Table 2-2. The data show a waste with high concentrations of solids (75 percent), low concentrations of water (less than 5 percent), approximately 20 percent disulfoton, 0.2 percent toluene, and less than 0.1 percent other BDAT list constituents. According to the data, no BDAT list inorganics other than metals, BDAT list organochlorine pesticides, BDAT list phenoxyacetic acid herbicides, PCBs, or dioxins and furans should be present in K037 wastes.

Table 2-1 Constituent Analysis of Untreated K037 Waste

Constituent	Concentration (wt. %)
Disulfoton	20
Toluene	0.2
Water	4.7
Solids (filter paper and diatomaceous earth filter aid)	75
Other BDAT list constituents	<0.1
Total	100 %

References:

1. USEPA 1987a. Onsite Engineering Report for K037.
2. Personal communication with J. J. Lonsinger, Environmental Control Manager, Mobay Corporation, Agricultural Chemicals Division, February 9, 1987.

Table 2-2 BDAT List Constituent Concentration and Other Data

BDAT reference no.	BDAT list constituent	Untreated K037 waste concentration (mg/kg) (1)	(2)
	Volatile Organics		
43	Toluene	201-2,000	<25,000
	Semivolatile Organics		
70	bis(2-ethylhexyl) phthalate	<250-500	-
	Metals		
155	Arsenic	<2.0-3.1	-
156	Barium	18-39	-
158	Cadmium	3.3-10	-
159	Chromium	43-93	-
160	Copper	7.0-24	-
161	Lead	5.6-28	-
163	Nickel	46-130	-
167	Vanadium	7-10	-
168	Zinc	89-190	-
	Organophosphorous Insecticides		
195	Disulfoton	104,000-246,000	0-100,000
	Other Parameters		
	Solids (filter paper and diatomaceous earth filter aid)	-	<750,000
	Water	-	125,000-225,000

References:

1. USEPA 1987a. Onsite Engineering Report for K037.
2. Personal communication with J.J. Lonsinger, Environmental Control Manager, Mobay Corporation, Agricultural Chemicals Division, February 9, 1987.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section describes the applicable treatment technologies, demonstrated treatment technologies, and performance data for the treatment of K037. Since the waste characterization data in Section 2 reveal untreated K037 wastes containing high BDAT list organic concentrations and high filterable solids, the technologies considered to be applicable are those that destroy or remove the various organic compounds in wastes with high filterable solids.

3.1 Applicable Treatment Technologies

The Agency has identified the following treatment technologies as being applicable for K037: batch distillation, incineration, and solvent extraction. Batch distillation can be used to separate components having widely different boiling points. Incineration technologies destroy the organic components in the waste feed. Solvent extraction removes organic constituents from a waste by exploiting the relatively high solubilities of the waste constituents in a particular solvent.

As stated previously, the Agency has identified these treatment technologies as applicable for treatment of K037 because the technologies are designed to destroy or remove the toxic organics present in untreated wastes with high filterable solids. The selection of the treatment technologies applicable for treating BDAT list organics in K037 waste is based on data submitted by industry, current literature sources, and field testing.

3.2 Demonstrated Treatment Technologies

The technologies demonstrated on this waste or on waste with similar parameters affecting treatment selection (i.e., high organic content, low water content, and high filterable solids content) are batch distillation and incineration including rotary kiln incineration and fluidized bed incineration. The Agency believes that solvent extraction is potentially applicable to the treatment of K037 waste; however, EPA does not have data on the characteristics of K037 waste that would allow the Agency to conclude that solvent extraction is "demonstrated" on similar wastes. The Agency does not believe that other technologies are applicable because various physical and chemical characteristics of this waste would not allow treatment.

EPA believes batch distillation and fluidized bed incineration to be demonstrated treatment technologies for K037 because both have been used to treat wastes with similar characteristics. The Agency knows of at least one facility using batch distillation and one facility using fluidized bed incineration for treatment of wastes similar to K037. However, EPA is not aware of any generator or TSD facility currently using either technology for treatment of wastes containing a large percentage of K037; nor are there performance data that demonstrate their effectiveness in treating the BDAT list constituents in K037 waste.

The Agency believes rotary kiln incineration is demonstrated to treat K037 since it is being used to treat wastes similar to K037 in parameters affecting treatment selection, including low water content, high organic content, and high solids concentration. To help develop treatment standards, EPA tested rotary kiln incineration to demonstrate the actual performance achievability. Since the Agency is not aware of any generator or TSD facilities currently using rotary kiln incineration for treatment of wastes containing a large percentage of K037, the K037 was incinerated in EPA's own in-house rotary kiln. Performance data collected by EPA for incineration of K037 using a rotary kiln incinerator are shown in Tables 4-1 through 4-6. A detailed discussion of incineration is presented in Section 3.2.1.

3.2.1. Incineration

This section addresses the commonly used incineration technologies: liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and finally important design and operating parameters. As appropriate the subsections are divided by type of incineration unit.

(1) Applicability and use of this technology.

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported, with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low suspended solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than currently practiced.

(2) Underlying principles of operation.

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process, some of the organic constituents will oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology is somewhat different from that for rotary kiln and fixed hearth incineration, in that the fluidized bed incinerator contains fluidizing sand and a freeboard section above the sand. The purpose of the fluidized bed is to both volatilize the waste and combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of a fluidized bed incinerator than in that of a rotary kiln or fixed hearth incinerator because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The freeboard generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of incineration technologies.

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and

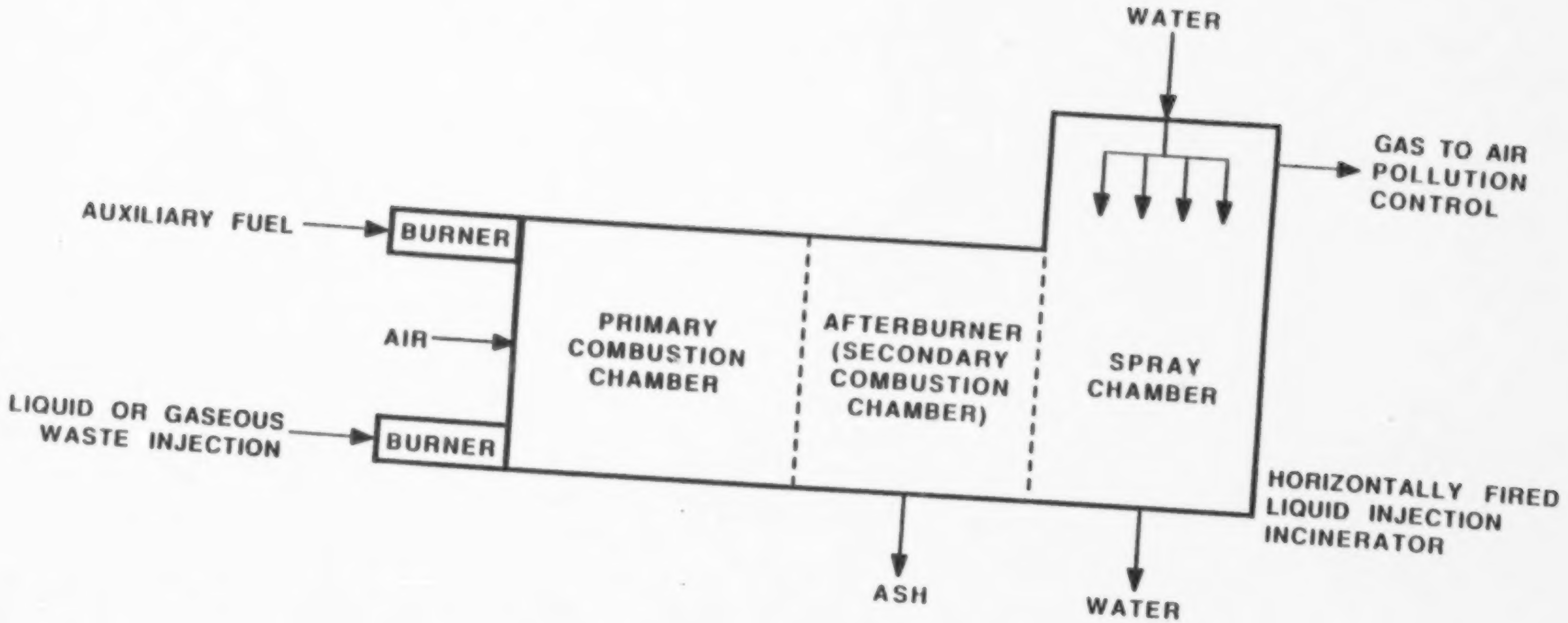
WATER
GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
BURNER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 3-1

LIQUID INJECTION INCINERATOR

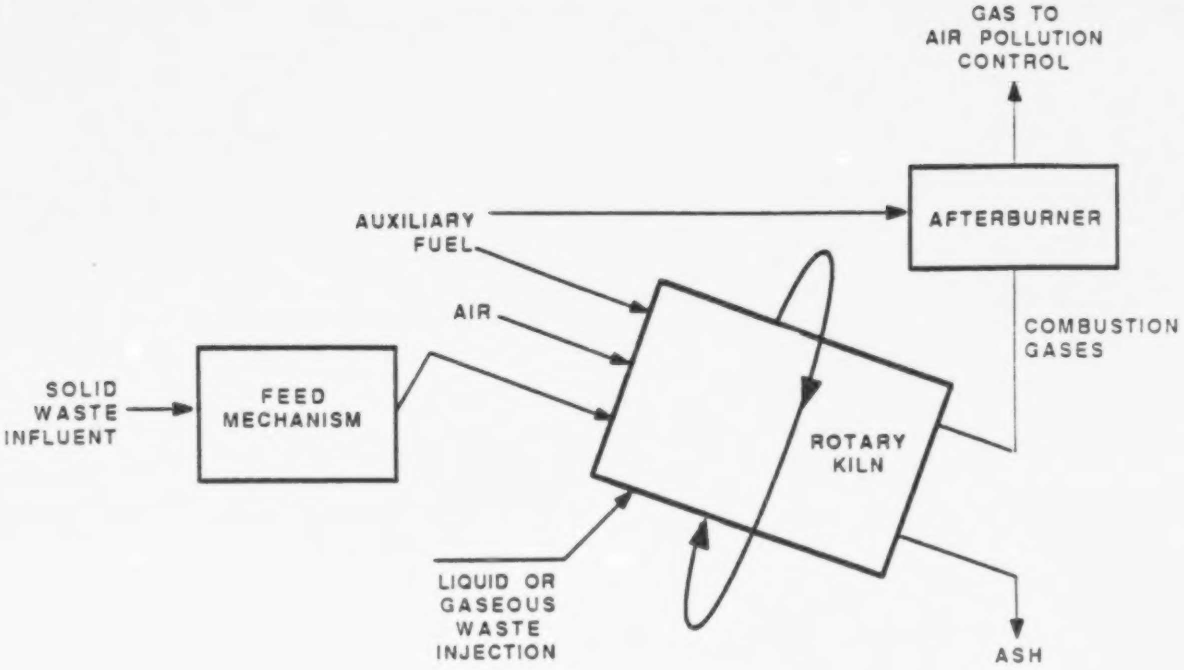
GAS TO AIR POLLUTION CONTROL
AFTERBURNER
AUXILIARY FUEL
AIR
COMBUSTION GASES
SOLID WASTE INFLUENT
FEED MECHANISM
ROTARY KILN
LIQUID OR GASEOUS WASTE INJECTION
ASH

FIGURE 3-2
ROTARY KILN INCINERATOR

uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone. (See Figure 3-3)

(d) Fixed hearth. Fixed hearth incinerators, also called controlled air or starved air incinerators, are another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove HCl and

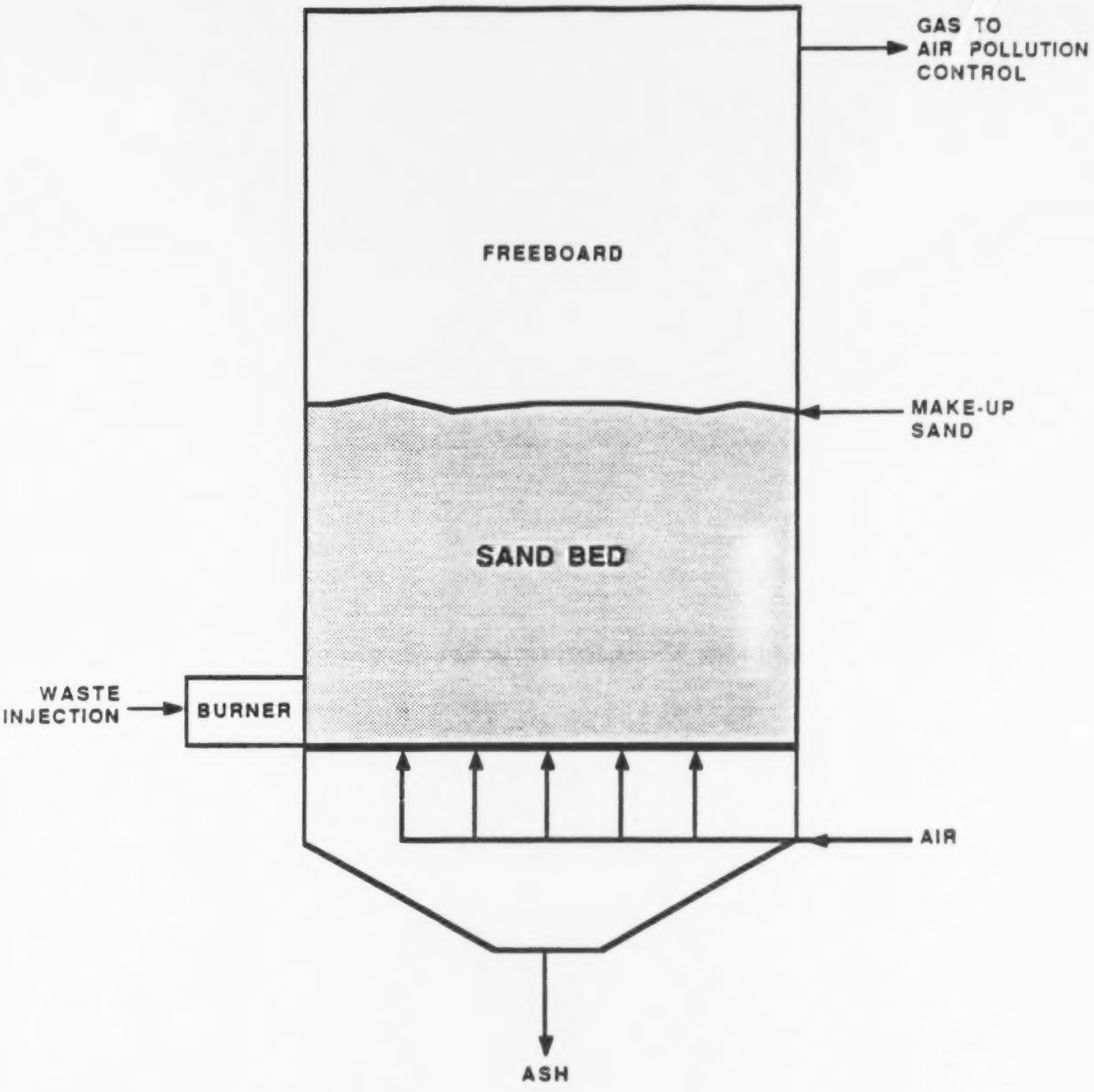
GAS TO
AIR POLLUTION
CONTROL
FREEBOARD
MAKE-UP
SAND
SAND BED
WASTE
INJECTION
BURNER
AIR
ASH

FIGURE 3-3
FLUIDIZED BED INCINERATOR

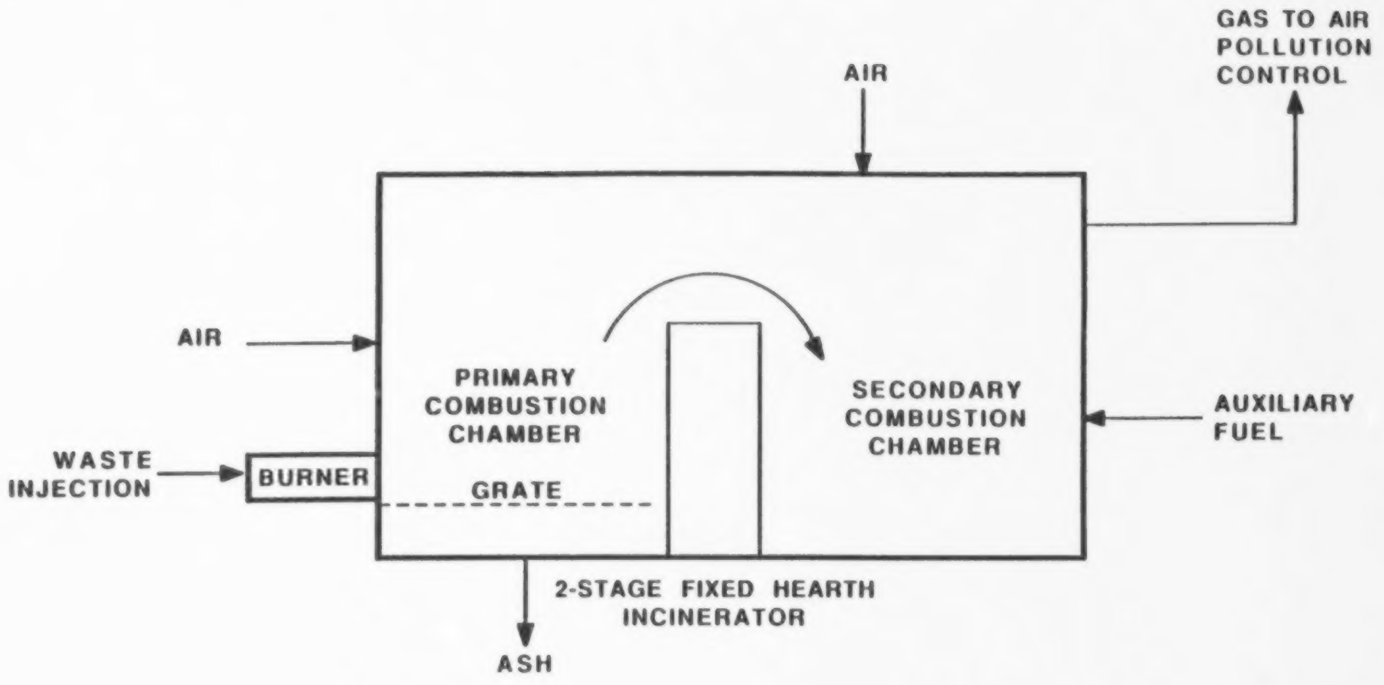
GAS TO AIR POLLUTION CONTROL
AIR
AIR
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
AUXILIARY FUEL
WASTE INJECTION
BURNER
GRATE
2-STAGE FIXED HEARTH INCINERATOR
ASH

FIGURE 3-4

FIXED HEARTH INCINERATOR

other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters less than one micron and require high efficiency collection devices to minimize air emissions. In addition, scrubber systems provide additional buffer against accidental releases of incompletely destroyed waste products due to poor combustion efficiency or combustion upsets, such as flame outs.

(4) Waste characteristics affecting performance (WCAP).

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested wastes. This parameter is being used as a surrogate indicator of activation energy which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; however, in practice this is not always the case. Other energy effects (e.g., vibrational effects, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these were rejected for reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction). Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data were rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics, once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than of the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of incinerator than of the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as, how it can be measured is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described Appendix D). In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, removal of this constituent from the waste will depend on its volatility. EPA is using boiling point as a surrogate of volatility of the constituent. Compounds with lower boiling points have higher vapor pressures and, therefore, would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Incineration design and operating parameters.

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are temperature, excess oxygen, and residence time. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposal restriction standards, EPA is concerned with these design parameters only when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned only with the waste characteristics that affect selection of the unit, not the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, it is more likely that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation which senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator that the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. It is important that the incinerator contain oxygen in excess of the stiochiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location from which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, one can calculate the volume of combustion gas. After both the Btu content and the expected combustion gas volume have been determined, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit was operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether sufficient energy is likely to be provided to the waste to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature is important, in that it provides an indirect measure of the energy input (i.e., Btu/hr) that is available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln including the length and diameter of the kiln, the waste feed rate, and the rate of rotation.

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as the RPM value increases, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously, in the section on "Underlying principles of operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas if halogens are present. The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were discussed under rotary kiln and will not be discussed here. The last, bed pressure differential, is important in that it provides an indication of the amount of turbulence and therefore indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase. The pressure drop through the bed should be continuously monitored and recorded to ensure that the design value is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln except that rate of rotation (i.e., RPMs) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under rotary kiln; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those previously discussed under "Liquid injection."

4. PERFORMANCE DATA BASE

The Agency collected the six data sets for untreated and treated wastes to characterize treatment of K037 using a rotary kiln treatment system. Treatment of K037 resulted in two treatment residuals: ash and scrubber water. Tables 4-1 through 4-6 present the six data sets of total waste concentration analyses for K037 waste samples, and the design and operating data for the treatment system. As shown by the operating data taken during collection of the samples, all six data sets reflect treatment by a well-operated system. Furthermore, all the data sets show treatment of the organic BDAT list constituents detected in the untreated wastes to nondetected levels in the treatment residuals.

Table 4-1 Rotary Kiln Incineration
EPA Collected Data
Sample Set #1

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (μg/l)
43	Toluene	640	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	<250	<2.0	NA	<50
155	Arsenic	3.1	10	<0.01	0.10
156	Barium	26	150	<0.045	0.91
157	Beryllium	<0.5	0.54	<0.005	<0.005
158	Cadmium	3.9	2.1	<0.015	0.059
1559	Chromium	70	80	0.079	0.15
160	Copper	24	610	3.3	4.7
161	Lead	28	54	0.029	6.6
163	Nickel	130	110	0.20	0.10
166	Thallium	<2.5	<2.5	<0.015	<0.015
167	Vanadium	8	82	0.93	<0.1
168	Zinc	190	290	0.64	16
195	Disulfoton	171,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1778-1818°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table 4-2 Rotary Kiln Incineration
EPA Collected Data
Sample Set #2

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (μg/l)
43	Toluene	530	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	<250	<2.0	NA	<50
155	Arsenic	2.4	5.0	<0.01	0.26
156	Barium	39	140	<0.045	0.19
157	Beryllium	<0.5	0.51	<0.005	<0.005
158	Cadmium	3.9	<2.0	<0.015	0.062
159	Chromium	73	93	0.22	0.21
160	Copper	12	940	10	4.7
161	Lead	12	66	0.013	11
163	Nickel	90	110	0.58	<0.1
166	Thallium	<2.5	<2.5	<0.015	<0.015
167	Vanadium	7	80	1.8	<0.1
168	Zinc	89	330	0.45	4.2
195	Disulfoton	104,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1778-1818°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table 4-3 Rotary Kiln Incineration
EPA Collected Data
Sample Set #3

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
43	Toluene	1,300	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	<250	<2.0	NA	<50
155	Arsenic	<2.0	25	0.022	0.22
156	Barium	18	130	0.049	0.22
157	Beryllium	<0.5	<0.5	<0.005	<0.005
158	Cadmium	3.8	<2.0	<0.015	0.073
159	Chromium	43	100	0.13	0.19
160	Copper	7.0	630	1.1	3.9
161	Lead	5.6	25	<0.01	3.6
163	Nickel	46	180	0.19	<0.1
166	Thallium	<2.5	<2.5	<0.015	<0.015
167	Vanadium	7	61	0.97	<0.1
168	Zinc	110	840	0.75	2.7
195	Disulfoton	246,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1778-1818°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table 4-4 Rotary Kiln Incineration
EPA Collected Data
Sample Set #4

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
43	Toluene	630	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	<250	<2.0	NA	<50
155	Arsenic	<2.0	15	<0.01	0.23
156	Barium	28	150	0.075	0.18
157	Beryllium	<0.5	<0.5	<0.005	<0.005
158	Cadmium	5.3	<2.0	<0.015	0.063
159	Chromium	85	110	0.074	0.090
160	Copper	21	460	3.0	4.0
161	Lead	22	15	0.017	4.0
163	Nickel	120	160	0.24	<0.1
166	Thallium	<2.5	<2.5	<0.015	<0.015
167	Vanadium	9	78	1.1	<0.1
168	Zinc	180	620	2.7	0.97
195	Disulfoton	186,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1830-1897°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table 4-5 Rotary Kiln Incineration
EPA Collected Data
Sample Set #5

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
43	Toluene	201	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	<250	<2.0	NA	<50
155	Arsenic	<2.0	5.0	<0.01	0.29
156	Barium	22	140	1.1	0.30
157	Beryllium	<0.5	<0.5	<0.005	<0.005
158	Cadmium	3.3	<2.0	<0.015	0.11
159	Chromium	50	88	0.26	0.13
160	Copper	15	380	4.3	6.2
161	Lead	12	15	0.021	6.8
163	Nickel	61	110	0.41	<0.1
166	Thallium	<2.5	<2.5	<0.015	0.02
167	Vanadium	10	77	1.8	<0.1
168	Zinc	110	450	4.8	1.7
195	Disulfoton	181,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1830-1897°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table 4-6 Rotary Kiln Incineration
EPA Collected Data
Sample Set #6

ANALYTICAL DATA:

BDAT Reference No.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (μg/l)
43	Toluene	2000	<10	NA	<10
70	Bis(2-ethylhexyl)phthalate	500	<2.0	NA	<50
155	Arsenic	<2.0	20	<0.01	0.45
156	Barium	33	170	0.1	0.39
157	Beryllium	<0.5	0.71	<0.005	<0.005
158	Cadmium	10	<2.0	<0.015	0.16
159	Chromium	93	87	<0.045	0.17
160	Copper	16	240	0.15	6.3
161	Lead	8.2	20	<0.01	11
163	Nickel	120	110	0.59	0.11
166	Thallium	<2.5	<2.5	<0.015	0.02
167	Vanadium	8	88	0.25	<0.1
168	Zinc	120	330	0.16	2.3
195	Disulfoton	192,000	<0.0335	NA	<1.00

DESIGN AND OPERATING DATA:

Kiln	Design value	Operating value
Temperature	1832°F	1830-1897°F
Revolutions per minute	0.2 rpm	0.2 rpm
Afterburner		
Temperature	2200°F	2043-2063°F
Excess oxygen	6-8%	8%
Carbon monoxide	<1000 ppm	<1 ppm

NA - Not Applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY FOR K037

This section presents the rationale for the determination of best demonstrated available technology (BDAT) for K037 nonwastewaters and wastewaters. As discussed in Section 1, the Agency examines all available data for the technologies that have been demonstrated for a particular waste to determine whether one of the demonstrated technologies performs significantly better than another. Next, the "best" performing of these technologies is evaluated to determine whether it is "available," i.e., whether it is (1) commercially available and (2) provides "substantial" treatment of the waste.

K037 waste is an organic nonwastewater for the purpose of determining the applicability of the BDAT treatment standards, since wastewaters are defined as wastes containing less than 1 percent (weight basis) filterable solids and less than 1 percent (weight basis) total organic carbon. However, demonstrated technologies for K037 nonwastewaters produce both nonwastewater and wastewater residuals. BDAT must therefore be identified for both types of waste streams.

5.1 Nonwastewaters

The demonstrated technologies for K037 nonwastewaters are batch distillation and incineration. The only treatment performance data available to the Agency are for treatment of K037 using rotary kiln incineration. It is therefore not possible to directly compare performance achieved by these two demonstrated technologies, or compare rotary kiln incineration to other forms of incineration, such as fluidized bed.

All performance data for K037 incineration were reviewed and assessed in relation to the design and operating parameters of the facility at the time of the test; the Agency concluded that the data were developed from a well-designed and well-operated facility. The quality assurance/quality control analyses conducted on the data and the analytical tests used to assess treatment performance were also reviewed and found to be satisfactory. All available data were therefore used to evaluate BDAT for this waste stream.

Nevertheless, the Agency has determined that rotary kiln incineration achieves better treatment of organics in K037 than does batch distillation. This is because incineration destroys the hazardous organic components of this waste, whereas batch distillation only concentrates them into a lower volume residual, which itself may require incineration. The Agency also concludes that fluidized bed units would not produce better treatment than rotary kilns because fluidized bed operating temperatures are lower than rotary kiln temperatures. Rotary kiln incineration is therefore the best demonstrated treatment technology for K037 organic nonwastewaters.

Rotary kiln incineration is also a widely available commercial technology. It achieves substantial treatment, as demonstrated by the accuracy-adjusted performance data presented in Section 4. Concentrations of organics (disulfoton) in the untreated waste were

186,000 mg/kg; concentrations in the treated residual (incinerator ash, a nonwastewater) were below detection limits. EPA concludes that rotary kiln incineration is available for K037 organic nonwastewaters and is therefore the best demonstrated available treatment for K037.

Incineration of K037 does, however, produce incinerator ash, a nonwastewater residual for which BDAT must also be established. Although performance data from the test conducted on incineration of K037 in a rotary kiln indicated the presence of some metals, this waste is listed as an organics waste only. Performance data for this waste indicate that organics residuals in the treated waste are below detection limits. The Agency concludes that no additional treatment of nonwastewater residuals from incineration of K037 is needed and that incineration is therefore BDAT for all nonwastewaters associated with the treatment of K037 waste.

5.2 Wastewaters

Treatment of K037 wastes in a rotary kiln incinerator produces one wastewater treatment stream--scrubber water from the air pollution control equipment of the incinerator.

Performance tests indicate that concentrations of disulfoton in scrubber water from K037 incineration are below detection limits. Since the input waste contains 186,000 mg/kg organics (disulfoton), this represents substantial treatment for organics in scrubber water. Because the Agency concludes that no additional treatment of scrubber water would significantly improve on this performance, rotary kiln incineration is also BDAT for wastewater residuals from treatment of K037 nonwastewater.

6. SELECTION OF REGULATED CONSTITUENTS

As discussed in Section 1, the Agency has developed a BDAT list of hazardous constituents (Table 1-1) from which the constituents to be regulated are selected. The list is an expanding list that does not preclude the addition of new constituents as additional key parameters are identified. The list is divided into the following categories: volatile organics, semivolatile organics, metals, inorganics other than metals, pesticides, PCBs, and dioxins and furans.

This section describes the step-by-step process used to select the pollutants to be regulated. The selected constituents must be present in the untreated waste and must be treatable by the chosen BDAT, rotary kiln incineration, as discussed in Section 5. Moreover, the regulated constituents are those compounds that are significantly reduced, and such reduction ensures that the recommended BDAT is the most effective treatment for the K037 waste. Using this definition and the major BDAT list constituents identified in Section 2, two constituents, toluene and disulfoton, are selected as the regulated constituents for K037 for which treatment standards are developed in Section 7 of this report.

6.1 Identification of Constituents in the Untreated Waste

Table 6-1 presents the BDAT list constituents as discussed in Section 1. The table indicates (1) which of the BDAT list constituents were analyzed for in the untreated waste and the treated waste and (2) of those analyzed for, which were detected. Of the 231 BDAT list constituents, 213 were analyzed for and the only constituents that were

Table 6-1 Status of BDAT List Constituent Presence in Untreated K037 Waste

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile organics		
222.	Acetone	NA	
1.	Acetonitrile	ND	
2.	Acrolein	ND	
3.	Acrylonitrile	ND	
4.	Benzene	ND	
5.	Bromodichloromethane	ND	
6.	Bromomethane	ND	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	NA	
8.	Carbon disulfide	ND	
9.	Chlorobenzene	ND	
10.	2-Chloro-1,3-butadiene	ND	
11.	Chlorodibromomethane	ND	
12.	Chloroethane	ND	
13.	2-Chloroethyl vinyl ether	ND	
14.	Chloroform	ND	
15.	Chloromethane	ND	
16.	3-Chloropropene	ND	
17.	1,2-Dibromo-3-chloropropane	ND	
18.	1,2-Dibromoethane	ND	
19.	Dibromomethane	ND	
20.	trans-1,4-Dichloro-2-butene	ND	
21.	Dichlorodifluoromethane	ND	
22.	1,1-Dichloroethane	ND	
23.	1,2-Dichloroethane	ND	
24.	1,1-Dichloroethylene	ND	
25.	trans-1,2-Dichloroethene	ND	
26.	1,2-Dichloropropane	ND	
27.	trans-1,3-Dichloropropene	ND	
28.	cis-1,3-Dichloropropene	ND	
29.	1,4-Dioxane	ND	
224.	2-Ethoxyethanol	ND	
225.	Ethyl acetate	ND	
226.	Ethyl benzene	ND	
30.	Ethyl cyanide	ND	
227.	Ethyl ether	NA	
31.	Ethyl methacrylate	ND	
214.	Ethylene oxide	NA	
32.	Iodomethane	ND	
33.	Isobutyl alcohol	ND	
228.	Methanol	NA	
34.	Methyl ethyl ketone	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status^a	Believed to be present
	Volatile organics (continued)		
229.	Methyl isobutyl ketone	NA	
35.	Methyl methacrylate	ND	
37.	Methacrylonitrile	ND	
38.	Methylene chloride	ND	
230.	2-Nitropropane	ND	
39.	Pyridine		
40.	1,1,1,2-Tetrachloroethane	ND	
41.	1,1,2,2-Tetrachloroethane	ND	
42.	Tetrachloroethene	ND	
43.	Toluene	201-2,000	
44.	Tribromomethane	ND	
45.	1,1,1-Trichloroethane	ND	
46.	1,1,2-Trichloroethane	ND	
47.	Trichloroethene	ND	
48.	Trichloromonofluoromethane	ND	
49.	1,2,3-Trichloropropane	ND	
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	
50.	Vinyl chloride	NA	
215.	1,2-Xylene	NA	
216.	1,3-Xylene	NA	
217.	1,4-Xylene	NA	
	Semivolatile organics		
51.	Acenaphthalene	ND	
52.	Acenaphthene	ND	
53.	Acetophenone	ND	
54.	2-Acetylaminofluorene	ND	
55.	4-Aminobiphenyl	ND	
56.	Aniline	ND	
57.	Anthracene	ND	
58.	Aramite	ND	
59.	Benz(a)anthracene	ND	
218.	Benzal chloride	NA	
60.	Benzenethiol	ND	
61.	Deleted		
62.	Benzo(a)pyrene	ND	
63.	Benzo(b)fluoranthene	ND	
64.	Benzo(ghi)perylene	ND	
65.	Benzo(k)fluoranthene	ND	
66.	p-Benzoquinone	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
67.	Bis(2-chloroethoxy)methane	ND	
68.	Bis(2-chloroethyl)ether	ND	
69.	Bis(2-chloroisopropyl)ether	ND	
70.	Bis(2-ethylhexyl)phthalate	<250-500	
71.	4-Bromophenyl phenyl ether	ND	
72.	Butyl benzyl phthalate	ND	
73.	2-sec-Butyl-4,6-dinitrophenol	ND	
74.	p-Chloroaniline	ND	
75.	Chlorobenzilate	ND	
76.	p-Chloro-m-cresol	ND	
77.	2-Chloronaphthalene	ND	
78.	2-Chlorophenol	ND	
79.	3-Chloropropionitrile	ND	
80.	Chrysene	ND	
81.	ortho-Cresol	ND	
82.	para-Cresol	ND	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	ND	
84.	Dibenzo(a,e)pyrene	ND	
85.	Dibenzo(a,i)pyrene	ND	
86.	m-Dichlorobenzene	ND	
87.	o-Dichlorobenzene	ND	
88.	p-Dichlorobenzene	ND	
89.	3,3'-Dichlorobenzidine	ND	
90.	2,4-Dichlorophenol	ND	
91.	2,6-Dichlorophenol	ND	
92.	Diethyl phthalate	ND	
93.	3,3'-Dimethoxybenzidine	ND	
94.	p-Dimethylaminoazobenzene	ND	
95.	3,3'-Dimethylbenzidine	ND	
96.	2,4-Dimethylphenol	ND	
97.	Dimethyl phthalate	ND	
98.	Di-n-butyl phthalate	ND	
99.	1,4-Dinitrobenzene	ND	
100.	4,6-Dinitro-o-cresol	ND	
101.	2,4-Dinitrophenol	ND	
102.	2,4-Dinitrotoluene	ND	
103.	2,6-Dinitrotoluene	ND	
104	Di-n-octyl phthalate	ND	
105.	Di-n-propylnitrosamine	ND	
106.	Diphenylamine	ND	
219.	Diphenylnitrosamine	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
107.	1,2-Diphenylhydrazine	ND	
108.	Fluoranthene	ND	
109.	Fluorene	ND	
110.	Hexachlorobenzene	ND	
111.	Hexachlorobutadiene	ND	
112.	Hexachlorocyclopentadiene	ND	
113.	Hexachloroethane	ND	
114.	Hexachlorophene	ND	
115.	Hexachloropropene	NA	
116.	Indeno(1,2,3-cd)pyrene	ND	
117.	Isosafrole	ND	
118.	Methapyrilene	ND	
119.	3-Methylcholanthrene	ND	
120.	4,4'-Methylenebis (2-chloroaniline)	ND	
36.	Methyl methanesulfonate	ND	
121.	Naphthalene	ND	
122.	1,4-Naphthoquinone	ND	
123.	1-Naphthylamine	ND	
124.	2-Naphthylamine	ND	
125.	p-Nitroaniline	ND	
126.	Nitrobenzene	ND	
127.	4-Nitrophenol	ND	
128.	N-Nitrosodi-n-butylamine	ND	
129.	N-Nitrosodiethylamine	ND	
130.	N-Nitrosodimethylamine	ND	
131.	N-Nitrosomethylethylamine	ND	
132.	N-Nitrosomorpholine	ND	
133.	N-Nitrosopiperidine	ND	
134.	n-Nitrosopyrrolidine	ND	
135.	5-Nitro-o-toluidine	ND	
136.	Pentachlorobenzene	ND	
137.	Pentachloroethane	ND	
138.	Pentachloronitrobenzene	ND	
139.	Pentachlorophenol	ND	
140.	Phenacetin	ND	
141.	Phenanthrene	ND	
142.	Phenol	ND	
220.	Phthalic anhydride	NA	
143.	2-Picoline	ND	
144.	Pronamide	ND	
145.	Pyrene	ND	
146.	Resorcinol	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
147.	Safrole	ND	
148.	1,2,4,5-Tetrachlorobenzene	ND	
149.	2,3,4,6-Tetrachlorophenol	ND	
150.	1,2,4-Trichlorobenzene	ND	
151.	2,4,5-Trichlorophenol	ND	
152.	2,4,6-Trichlorophenol	ND	
153.	Tris(2,3-dibromopropyl) phosphate	ND	
	Metals		
154.	Antimony	ND	
155.	Arsenic	<2-3.1	
156.	Barium	18-39	
157.	Beryllium	ND	
158.	Cadmium	3.3-10	
159.	Chromium (total)	43-93	
221.	Chromium (hexavalent)	NA	
160.	Copper	7-24	
161.	Lead	56-28	
162.	Mercury	ND	
163.	Nickel	46-130	
164.	Selenium	ND	
165.	Silver	ND	
166.	Thallium	ND	
167.	Vanadium	7-10	
168.	Zinc	89-130	
	Inorganics other than metals		
169.	Cyanide	-	
170.	Fluoride	-	
171.	Sulfide	-	
	Organochlorine pesticides		
172.	Aldrin	ND	
173.	alpha-BHC	ND	
174.	beta-BHC	ND	
175.	delta-BHC	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Organochlorine pesticides (continued)		
176.	gamma-BHC	ND	
177.	Chlordane	ND	
178.	DDD	ND	
179.	DDE	ND	
180.	DDT	ND	
181.	Dieldrin	ND	
182.	Endosulfan I	ND	
183.	Endosulfan II	ND	
184.	Endrin	ND	
185.	Endrin aldehyde	ND	
186.	Heptachlor	ND	
187.	Heptachlor epoxide	ND	
188.	Isodrin	ND	
189.	Kepone	ND	
190.	Methoxyclor	ND	
191.	Toxaphene	ND	
	Phenoxyacetic acid herbicides		
192.	2,4-Dichlorophenoxyacetic acid	ND	
193.	Silvex	ND	
194.	2,4,5-T	ND	
	Organophosphorous insecticides		
195.	Disulfoton	104,000-246,000	
196.	Famphur	ND	
197.	Methyl parathion	ND	
198.	Parathion	ND	
199.	Phorate	ND	
	PCBs		
200.	Aroclor 1016	ND	
201.	Aroclor 1221	ND	
202.	Aroclor 1232	ND	
203.	Aroclor 1242	ND	
204.	Aroclor 1248	ND	
205.	Aroclor 1254	ND	
206.	Aroclor 1260	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Dioxins and furans		
207.	Hexachlorodibenzo-p-dioxins	ND	
208.	Hexachlorodibenzofurans	ND	
209.	Pentachlorodibenzo-p-dioxins	ND	
210.	Pentachlorodibenzofurans	ND	
211.	Tetrachlorodibenzo-p-dioxins	ND	
212.	Tetrachlorodibenzofurans	ND	
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND	

ND = Not detected.

NA = Not analyzed.

X = Believed to be present based on engineering analysis of waste generating process.

Y = Believed to be present based on detection in treated residuals.

[a] Where concentrations are shown, units are mg/kg.

detected were toluene and bis(2-ethylhexyl)phthalate; certain metals such as arsenic, barium, cadmium, chromium, copper, lead, nickel, vanadium, and zinc; and the organophosphorous insecticide disulfoton. Eighteen constituents were not analyzed for because at the time the analysis was performed, those constituents were not on the BDAT constituent list. For those constituents identified as not detected (ND), it was assumed that they were present at or below detection limits or that some constituents were present in the untreated waste but masking or interference prevented their detection. Detection limits for K037 constituents in treated and untreated wastes are provided in Appendix C. A summary of the detected constituents and their concentrations is given in Table 6-2.

6.2 Comparison of Untreated and Treated Waste Data for the Major Constituents

Table 6-2 also presents the concentrations of major constituents in the treated waste residues, namely ash and scrubber water. The treated waste data demonstrate that the three detected organics -- toluene, disulfoton, and bis(2-ethylhexyl)phthalate -- were reduced significantly. This further indicates that the BDAT identified is effective in reducing the major organic constituents to nontreatable levels, and that the treatment residues do not need any additional organic treatment.

Because the concentrations of toluene, bis(2-ethylhexyl)phthalate, and disulfoton were reduced substantially, these compounds were regarded as potential regulated constituents. The Agency requires further analysis of constituents for which substantial reduction was not achieved

Table 6-2 BDAT List Constituents and Their Concentrations in Untreated Waste and Treatment Residues

BDAT reference no.	BDAT list constituent	Untreated waste (mg/kg)	Treated waste residue		
			Ash (mg/kg)	Ash TLCP (mg/l)	Scrubber water (ug/l)
43.	Toluene	201-2,000	<10	NA	<10
70.	Bis(2-ethylhexyl)-phthalate	<250-500	<2.0	NA	<50
155.	Arsenic	<2-3.1	5.25	<0.01-0.022	0.1-0.45
156.	Barium	18-39	130-170	<0.045-1.1	0.18-0.91
157.	Beryllium	<0.5	<0.5-0.54	<0.005	<0.005
158.	Cadmium	3.3-10	<2.0-2.1	<2.0	0.059-0.16
159.	Chromium	43-93	80-110	<0.045-0.26	0.09-0.21
160.	Copper	7-24	380-940	0.15-10	3.9-6.3
161.	Lead	5.6-28	15-66	<0.01-0.029	4-11
163.	Nickel	46-130	110-180	0.19-0.59	<0.1-0.11
166.	Thallium	<2.5	<2.5	0.015	<0.015
167.	Vanadium	7-10	61-88	0.25-1.8	<0.1
168.	Zinc	89-190	290-840	0.45-4.8	0.97-16
195.	Disulfoton	104,000-246,000	<0.0335	NA	<1.0

NA = Not applicable.

Reference: USEPA 1987. Onsite Engineering Report for K037.

to determine whether the reduction is significant. Statistical analysis would be required for this determination. As seen in Table 6-2, this step was not necessary.

Untreatable concentrations of metals were detected in the scrubber water and ash residuals. The amounts are too low to warrant metals treatment. Furthermore, since none of the detected BDAT list metals were treated by rotary kiln incineration, none were regarded as potential regulated constituents.

6.3 Selection of Regulated Constituents

Toluene and disulfoton are the only two BDAT list constituents selected as regulated constituents for K037. Using the analytical data for these constituents, the Agency developed BDAT treatment standards, which are discussed in the following section. The Agency did not select bis(2-ethylhexyl)phthalate as a regulated constituent because regulation of toluene and disulfoton will, the Agency believes, control other organics present in the untreated waste.

7. CALCULATION OF BDAT TREATMENT STANDARDS

The purpose of this section is to calculate the actual treatment standards for the regulated constituents identified in Section 6. EPA has six sets of influent and effluent data from one facility for treatment of K037 using rotary kiln incineration. As discussed in the introduction, the following steps were taken to derive the BDAT treatment standards for K037.

1. The Agency evaluated the data collected from the rotary kiln treatment system to determine whether any of the data represented poor design or operation of the treatment system. The available data show that none of the six data sets represents poor design or operation. All six data sets for rotary kiln incineration are used for regulation of the K037 waste.
2. Accuracy-corrected constituent concentrations were calculated for all BDAT-list constituents. An arithmetic average concentration level and a variability factor were determined for each BDAT list constituent regulated in this waste, as shown in Table 7-1. The calculation of the variability factor is presented in Appendix A.
3. The BDAT treatment standard for each constituent regulated in this rulemaking was determined by multiplying the average accuracy-corrected total composition by the appropriate variability factor.

Table 7-1 summarizes the calculation of the treatment standards for K037 nonwastewaters and wastewaters. EPA believes the treated constituent concentrations substantially diminish the toxicity of K037.

Table 7-1 Regulated Constituents and Calculated Treatment Standards for K037

Matrix	Constituent (units)	Accuracy-corrected concentration Sample set #1	Sample set #2	Sample set #3	Sample set #4	Sample set #5	Sample set #6	Average treated waste concentration	Variability factor (VF)	Treatment standard (average x VF)
Nonwastewaters	Disulfoton (mg/kg)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	2.8	0.10
	Toluene (mg/kg)	10	10	10	10	10	10	10	2.8	28
Wastewaters	Disulfoton (mg/l)	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	2.8	0.003
	Toluene (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2.8	0.028

8. ACKNOWLEDGMENTS

This document was prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract No. 68-01-7053. Mr. James Berlow, Chief, Treatment Technology Section, Waste Treatment Branch, served as the EPA Program Manager during the preparation of this document and the development of treatment standards for the K037 waste. The technical project officer for the waste was Ms. Lisa Jones. Mr. Steven Silverman served as legal advisor.

Versar personnel involved with preparing this document included Mr. Jerome Strauss, Program Manager; Ms. Laura Fargo, Engineering Team Leader; Ms. Justine Alchowiak, Quality Assurance Officer; Mr. David Pepson, Senior Technical Reviewer; Mr. James Morgan, Technical Reviewer; Ms. Juliet Crumrine, Technical Editor; and the Versar secretarial staff, Ms. Linda Gardiner and Ms. Mary Burton.

Mr. Benjamin Blaney, Chief, Treatment Technology Staff, served as the ORD Program Manager for collection of treatment data for K037 waste. The ORD technical project officer was Mr. Ronald Turner. The K037 treatment test was conducted at the U.S. EPA Combustion Research Facility by Acurex Corporation, contractor to the Office of Research and Development. Field sampling for the test was conducted under the leadership of PEI Associates. Laboratory coordination and analysis were provided by Radian Corporation.

We greatly appreciate the cooperation of the company whose plant was sampled and who submitted detailed information to the U.S. EPA.

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APPENDIX A

STATISTICAL METHODS

A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

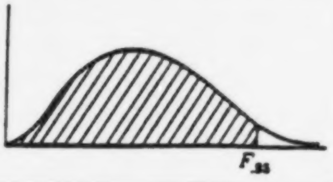
If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

95th PERCENTILE VALUES FOR THE *F* DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)



n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2{}_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

where:

$x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and
$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

Steam stripping				Biological treatment			
Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	[ln(effluent)]^2	Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	[ln(effluent)]^2
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-	-	23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$MSB = SSB/(k-1)$

$MSW = SSW/(N-k)$

Example 1 (Continued)

F = MSB/MSW

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10$, $n_2 = 5$, $N = 15$, $k = 2$, $T_1 = 23.18$, $T_2 = 12.46$, $T = 35.64$, $T^2 = 1270.21$

$T_1^2 = 537.31$ $T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

MSB = 0.10/1 = 0.10

MSW = 0.77/13 = 0.06

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

Steam stripping				Biological treatment			
Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum:							
	-	26.14	72.92	-	-	16.59	39.52
Sample Size:							
10	10	10	-	7	7	7	-
Mean:							
2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:							
3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:							
-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$MSB = SSB/(k-1)$

$MSW - SSW/(N-k)$

Example 2 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7}\right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

$MSB = 0.25/1 = 0.25$

$MSW = 4.79/15 = 0.32$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	ln[(effluent)]^2
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	-
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

$$F = MSB/MSW$$

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4$, $N_2 = 7$, $N = 11$, $k = 2$, $T_1 = 14.49$, $T_2 = 38.90$, $T = 53.39$, $T^2 = 2850.49$, $T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{Mean}$$

where:

VF = estimate of daily maximum variability factor determined from a sample population of daily data;

C_{99} = estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = Exp(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data; and

Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{Mean}. \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \text{Exp}\ (\mu + 2.33\sigma) \qquad (2)$$
$$\text{Mean} = \text{Exp}\ (\mu + 0.5\sigma^2). \qquad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \text{Exp}\ (2.33\ \sigma - 0.5\sigma^2). \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

  $$\sigma = [\ln(UL) - \ln(LL)] / [(2)(2.33)] = [\ln(UL/LL)] / 4.66. \qquad (5)$$

  (Note that when LL = (0.1)(UL) as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494$.)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

APPENDIX B

ANALYTICAL QA/QC

The analytical methods used for analysis of the regulated constituents identified in Section 5 are listed in Table B-1. SW-846 methods (EPA's Test Methods for Evaluation Solid of Waste; Physical/Chemical Methods, SW-846, Third Edition, November 1986) are used in most cases for determining total constituent concentrations.

The accuracy determination for a constituent is based on the matrix spike recovery values. Tables B-2 and B-3 present the matrix spike recoveries for disulfoton and toluene total composition analyses for K037 residuals for the EPA-collected data.

The accuracy correction factors for disulfoton and toluene for each treatment residual are summarized in Tables B-2 and B-3. The accuracy correction factors were determined in accordance with the general methodology presented in the Introduction. For example, for disulfoton actual spike recovery data were obtained for analysis of both solid and liquid matrices, and the lowest percent recovery value was used to calculate the accuracy correction factor. An example of the calculation of a corrected constituent concentration value is shown below.

Analytical Value	% Recovery	Correction Factor	Corrected Value
0.0335 ppm	91	$\frac{100}{91} = 1.10$	1.10 x 0.0335 = 0.04 ppm

Table B-1 Analytical Methods for Regulated Constituents

Regulated constituent	Extraction method	Analytical method	Reference
Disulfoton	Specified in analytical method	8140	USEPA 1986b
Toluene	Specified in analytical method	5030, 8240	USEPA 1986b

Table B-2 Matrix Spike Recoveries for K037 Treated Solids - EPA-Collected Data

BDAT constituent	Original amount found (ug/l)	Sample Set #5			Sample Set #5 Duplicate			Accuracy correction factor[b]
		Spike added (ug/l)	Spike result (ug/l)	Percent recovery*	Spike added (ug/l)	Spike result (ug/l)	Percent recovery[a]	
Disulfoton	<0.007	0.173	0.157	91	0.173	0.164	95	1.10
Toluene	NC	25	NC	166	25	NC	165	1.00

NC = Not calculable because the only values available were the spike amount and the percent recovery.

[a] Percent recovery = [(spike result - original amount)/spike added].

[b] Accuracy correction factor = 100/percent recovery (using the lowest percent recovery value).

Reference: USEPA 1987. Onsite Engineering Report for K037.

Table B-3 Matrix Spike Recoveries for K037 Scrubber Water Sample - EPA-Collected Data

BDAT constituent	Original amount found (ug/l)	Sample Set #5			Sample Set #5 Duplicate			Accuracy correction factor[b]
		Spike added (ug/l)	Spike result (ug/l)	Percent recovery*	Spike added (ug/l)	Spike result (ug/l)	Percent recovery[a]	
Disulfoton	<0.2	5.18	4.88	94	5.18	5.28	102	1.06
Toluene	NC	25	NC	109	25	NC	116	1.00

NC = Not calculable because the only values available were the spike amount and the percent recovery.

[a] Percent recovery = [(spike result - original amount)/spike added].

[b] Accuracy Correction Factor = 100/Percent Recovery (using the lowest percent recovery value).

Reference: USEPA 1987. Onsite Engineering Report for K037.

APPENDIX C

DETECTION LIMITS FOR K037 WASTE AND TREATMENT RESIDUALS

Table C-1 shows analytical detection limits for the BDAT list constituents analyzed for K037 waste.

Table C-1 Detection Limits for K037 Untreated and Treated Samples

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Volatiles					
222.	Acetone	67-64-1	NL	NL	NL	NL
1.	Acetonitrile	75-05-8	10,000	1000	1000	1000
2.	Acrolein	107-02-8	25,000	2500	2500	2500
3.	Acrylonitrile	107-13-1	500	50	50	50
4	Benzene	71-43-2	100	10	10	10
5.	Bromodichloromethane	75-27-4	100	10	10	10
6.	Bromomethane	74-83-9	500	50	50	50
223.	n-Butyl alcohol	71-36-3	NL	NL	NL	NL
7.	Carbon tetrachloride	56-23-5	100	10	10	10
8.	Carbon disulfide	75-15-0	500	50	50	50
9.	Chlorobenzene	108-90-7	100	10	10	10
10.	2-Chloro-1,3-butadiene	126-99-8	2500	250	250	250
11.	Chlorodibromomethane	124-48-1	100	10	10	10
12.	Chloroethane	75-00-3	500	50	50	50
13.	2-Chloroethyl vinyl ether	110-75-8	10,000	1000	1000	1000
14.	Chloroform	67-66-3	100	10	10	10
15.	Chloromethane	74-87-3	500	50	50	50
16.	3-Chloropropene	107-05-1	100	10	10	10
17.	1,2-Dibromo-3-chloropropane	96-12-8	100	10	10	10
18.	1,2-Dibromoethane	106-93-4	100	10	10	10
19.	Dibromomethane	74-95-3	100	10	10	10
20.	trans-1,4-Dichloro-2-butene	110-57-6	2500	250	250	250
21.	Dichlorodifluoromethane	75-34-3	100	10	10	10
22.	1,1-Dichloroethane	107-06-2	100	10	10	10
23.	1,2-Dichloroethane	75-35-4	100	10	10	10
24.	1,1-Dichloroethylene	156-60-5	100	10	10	10
25.	trans-1,2-Dichloroethene	78-87-5	100	10	10	10
26.	1,2-Dichloropropane	10061-02-6	250	25	25	25
27.	trans-1,3-Dichloropropene	10061-01-5	250	25	25	25
28.	cis-1,3-Dichloropropene	123-91-1	250	25	25	25
29.	1,4-Dioxane	107-12-0	NA	NA	NA	NA
224.	2-Ethoxyethanol	110-80-5	NL	NL	NL	NL

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Volatiles (continued)					
225.	Ethyl acetate	141-78-6	NL	NL	Nl	NL
226.	Ethyl benzene	100-41-4	NL	NL	NL	NL
30.	Ethyl cyanide	97-63-2	NA	NA	NA	NA
227.	Ethyl ether	60-29-7	NL	NL	NL	NL
31.	Ethyl methacrylate	75-21-8	500	50	50	50
214.	Ethylene oxide	75-21-8	NL	NL	NL	NL
32.	Iodomethane	74-88-4	100	10	10	10
33.	Isobutyl alcohol	78-83-1	NA	NA	NA	NA
228.	Methanol	67-56-1	NL	NL	NL	NL
34.	Methyl ethyl ketone	78-93-3	2500	250	250	250
229.	Methyl isobutyl ketone	108-10-1	NL	NL	NL	NL
35.	Methyl methacrylate	80-62-6	500	50	50	50
36.	Methyl methanesulfonate	66-27-3	NA	NA	NA	NA
37.	Methacrylonitrile	126-98-7	NA	NA	NA	NA
38.	Methylene chloride	75-09-2	2500	250	250	250
230.	2-Nitropropane	79-46-9	NL	NL	NL	NL
39	Pyridine	110-86-1	-	-	-	-
40.	1,1,1,2-Tetrachloroethane	630-20-6	100	10	10	10
41.	1,1,2,2-Tetrachloroethane	79-34-6	100	10	10	10
42.	Tetrachloroethene	127-18-4	100	10	10	10
43.	Toluene	108-88-3	100	10	10	10
44.	Tribromomethane	75-25-2	100	10	10	10
45.	1,1,1-Trichloroethane	71-55-6	100	10	10	10
46.	1,1,2-Trichloroethane	79-00-5	100	10	10	10
47.	Trichloroethene	79-01-6	100	10	10	10
48.	Trichloromonofluoromethane	75-69-4	100	10	10	10
49.	1,2,3-Trichloropropane	96-18-4	2500	250	250	250
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	NL	NL	NL	NL
50.	Vinyl chloride	75-01-4	500	50	50	50
215.	1,2-Xylene	97-47-6	NL	NL	NL	NL
216.	1,3-Xylene	108-38-3	NL	NL	NL	NL
217.	1,4-Xylene	106-44-5	NL	NL	NL	NL

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Semivolatiles					
51.	Acenaphthalene	208-96-8	250	2.0	50	50
52.	Acenaphthene	83-32-9	250	2.0	50	50
53.	Acetophenone	96-86-2	250	2.0	50	50
54.	2-Acetylaminofluorene	53-96-3	25,000	200.0	5,000	5,000
55.	4-Aminobiphenyl	92-67-1	5,000	35.0	1,000	1,000
56.	Aniline	62-53-3	500	3.5	100	100
57.	Anthracene	120-12-7	250	2.0	50	50
58.	Aramite	140-57-8	NA	NA	NA	NA
59.	Benz(a)anthracene	56-55-3	250	2.0	50	50
218.	Benzal chloride	98-87-3	NL	NL	NL	NL
60.	Benzal chloride	98-87-3	NA	NA	NA	NA
61.	Benzenethiol	108-98-5	25,000	200.0	5,000	5,000
62.	Benzo(a)pyrene	50-32-8	250	2.0	50	50
63.	Benzo(b)fluoranthene	205-99-2	250	2.0	50	50
64.	Benzo(ghi)perylene	191-24-2	250	2.0	50	50
65.	Benzo(k)fluoranthene	207-08-9	250	2.0	50	50
66.	p-Benzoquinone	106-51-4	25,000	200.0	5,000	5,000
67.	Bis(2-chloroethoxy)methane	111-91-1	250	2.0	50	50
68.	Bis(2-chloroethyl)ether	111-44-4	250	2.0	50	50
69.	Bis(2-chloroisopropyl)ether	39638-32-9	250	2.0	50	50
70.	Bis(2-ethylhexyl)phthalate	117-81-7	250	2.0	50	50
71.	4-Bromophenyl phenyl ether	101-55-3	250	2.0	50	50
72.	Butyl benzyl phthalate	85-68-7	250	2.0	50	50
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7	NA	NA	NA	NA
74.	p-Chloroaniline	106-47-8	2,500	2.0	500	500
75.	Chlorobenzilate	510-15-6	NA	NA	NA	NA
76.	p-Chloro-m-cresol	59-50-7	250	2.0	50	50
77.	2-Chloronaphthalene	91-58-7	250	2.0	50	50
78.	2-Chlorophenol	95-57-8	250	2.0	50	50
79.	3-Chloropropionitrile	542-76-7	NA	NA	NA	NA
80.	Chrysene	218-01-9	250	2.0	50	50
81.	ortho-Cresol	95-48-7	250	2.0	50	50
82.	para-Cresol	106-44-5	250	2.0	50	50

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (μg/l)
	Semivolatiles (continued)					
232.	Cyclohexanone	108-94-1	NL	NL	NL	NL
83.	Dibenz(a,h)anthracene	53-70-3	250	2.0	50	50
84.	Dibenzo(a,e)pyrene	192-65-4	250	2.0	50	50
85.	Dibenzo(a,i)pyrene	189-55-9	250	2.0	50	50
86.	m-Dichlorobenzene	541-73-1	250	2.0	50	50
87.	o-Dichlorobenzene	95-50-1	250	2.0	50	50
88.	p-Dichlorobenzene	106-46-7	250	2.0	50	50
89.	3,3'-Dichlorobenzidine	91-94-1	500	3.5	100	100
90.	2,4-Dichlorophenol	120-83-2	250	2.0	50	50
91.	2,6-Dichlorophenol	87-65-0	250	2.0	50	50
92.	Diethyl phthalate	84-66-2	250	2.0	50	50
93.	3,3'-Dimethoxybenzidine	119-90-4	250,000	2000.0	50,000	50,000
94.	p-Dimethylaminoazobenzene	60-11-7	5,000	35.0	1,000	1,000
95.	3,3'-Dimethylbenzidine	119-93-7	250,000	2000.0	50,000	50,000
96.	2,4-Dimethylphenol	105-67-9	250	2.0	50	50
97.	Dimethyl phthalate	131-11-3	250	2.0	50	50
98.	Di-n-butyl phthalate	84-74-2	250	2.0	50	50
99.	1,4-Dinitrobenzene	100-25-4	2,500	20.0	500	500
100.	4,6-Dinitro-o-cresol	534-52-1	1,250	10.0	250	250
101.	2,4-Dinitrophenol	51-28-5	1,250	10.0	250	250
102.	2,4-Dinitrotoluene	121-14-2	250	2.0	50	50
103.	2,6-Dinitrotoluene	606-20-2	250	2.0	50	50
104.	Di-n-octyl phthalate	117-84-0	250	2.0	50	50
105.	Di-n-propylnitrosamine	621-64-7	-	-	-	-
106.	Diphenylamine	122-39-4	250	2.0	50	50
219.	Diphenylnitrosamine	86-30-6	250	2.0	50	50
107.	1,2-Diphenylhydrazine	122-66-7	250	2.0	50	50
108.	Fluoranthene	206-44-0	250	2.0	50	50
109.	Fluorene	86-73-7	250	2.0	50	50
110.	Hexachlorobenzene	118-74-1	250	2.0	50	50
111.	Hexachlorobutadiene	87-68-3	250	2.0	50	50
112.	Hexachlorocyclopentadiene	77-47-4	250	2.0	50	50
113.	Hexachloroethane	67-72-1	250	2.0	50	50

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Semivolatiles (continued)					
114.	Hexachlorophene	70-30-4	NA	NA	NA	NA
115.	Hexachloropropene	1888-71-7	250	2.0	50	50
116.	Indeno(1,2,3-cd)pyrene	193-39-5	250	2.0	50	50
117.	Isosafrole	120-58-1	2,500	20.0	500	500
118.	Methapyrilene	91-80-5	NA	NA	NA	NA
119.	3-Methylcholanthrene	56-49-5	2500	20.0	500	500
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4	5,000	35.0	1,000	1,000
121.	Naphthalene	91-20-3	250	2.0	50	50
122.	1,4-Naphthoquinone	130-15-4	2,500	20.0	500	500
123.	1-Naphthylamine	134-32-7	2,500	20.0	500	500
124.	2-Naphthylamine	91-59-8	2,500	20.0	500	500
125.	p-Nitroaniline	100-01-6	1,250	10.0	250	250
126.	Nitrobenzene	98-95-3	250	2.0	50	50
127.	4-Nitrophenol	100-02-7	1,250	10.0	250	250
128.	N-Nitrosodi-n-butylamine	924-16-3	2,500	20.0	500	500
129.	N-Nitrosodiethylamine	55-18-5	2,500	20.0	500	500
130.	N-Nitrosodimethylamine	62-75-9	2,500	20.0	500	500
131.	N-Nitrosomethylethylamine	10595-95-6	2,500	20.0	500	500
132.	N-Nitrosomorpholine	59-89-2	5,000	35.0	1,000	1,000
133.	N-Nitrosopiperidine	100-75-4	5,000	35.0	1,000	1,000
134.	n-Nitrosopyrrolidine	930-55-2	5,000	35.0	1,000	1,000
135.	5-Nitro-o-toluidine	99-65-8	5,000	35.0	1,000	1,000
136.	Pentachlorobenzene	608-93-5	250	2.0	50	50
137.	Pentachloroethane	76-01-7	250	2.0	50	50
138.	Pentachloronitrobenzene	82-68-8	2,500	20.0	500	500
139.	Pentachlorophenol*	87-86-5	1,250	10.0	250	250
140.	Phenacetin	62-44-2	2,500	20.0	500	500
141.	Phenanthrene	85-01-8	250	2.0	50	50
142.	Phenol	108-95-2	250	2.0	50	50
220.	Phthalic anhydride	85-44-9	NL	NL	NL	NL
143.	2-Picoline	109-06-8	2,500	20.0	500	500

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Semivolatiles (cont.)					
144.	Pronamide	23950-58-5	2,500	20.0	500	500
145.	Pyrene	129-00-0	250	2.0	50	50
146.	Resorcinol	108-46-3	25,000	2000.0	5,000	5,000
147.	Safrole	94-59-7	2,500	20.0	500	500
148.	1,2,4,5-Tetrachlorobenzene	95-94-3	2,500	2.0	50	50
149.	2,3,4,6-Tetrachlorophenol	58-90-2	2,500	20.0	500	500
150.	1,2,4-Trichlorobenzene	120-82-1	250	2.0	50	50
151.	2,4,5-Trichlorophenol	95-95-4	1,250	10.0	250	250
152.	2,4,6-Trichlorophenol	88-06-2	250	2.0	50	50
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7	NA	NA	NA	NA
	Metals					
154.	Antimony	7440-36-0	17.0	17.0	0.3	0.3
155.	Arsenic	7440-38-2	2.0	2.0	0.01	0.01
156.	Barium	7440-39-3	1.0	1.0	0.045	0.045
157.	Beryllium	7440-41-7	0.5	0.5	0.005	0.005
158.	Cadmium	7440-43-9	2.0	2.0	0.015	0.015
159.	Chromium (total)	7440-47-32	3.5	3.5	0.045	0.045
221.	Chromium (hexavalent)		NL	NL	NL	NL
160.	Copper	7440-50-8	3.0	3.0	0.05	0.05
161.	Lead	7439-92-1	1.0	1.0	0.01	0.01
162.	Mercury	7439-97-6	1.25	1.25	0.001	0.001
163.	Nickel	7440-02-0	7.5	7.5	0.1	0.1
164.	Selenium	7782-49-2	2.0	2.0	0.015	0.015
165.	Silver	7440-22-4	3.5	3.5	0.045	0.045
166.	Thallium	7440-28-0	2.5	2.5	0.015	0.015
167.	Vanadium	7440-62-2	4.0	4.0	0.1	0.1
168.	Zinc	7440-66-6	1.0	1.0	0.03	0.03

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Inorganics					
169.	Cyanide	57-12-5	-	-	-	0.05
170.	Fluoride	16964-48-8	-	-	-	0.05
171.	Sulfide	8496-25-8	-	-	-	5
	Organochlorine pesticides					
172.	Aldrin	309-00-2	7.5	5.0	-	0.15
173.	alpha-BHC	319-84-6	4.0	2.5	-	0.10
174.	beta-BHC	319-85-7	7.5	5.0	-	0.15
175.	delta-BHC	319-86-8	7.5	5.0	-	0.15
176.	gamma-BHC	58-89-9	5.0	5.0	-	0.10
177.	Chlordane	57-74-9	100	75	-	1.00
178.	DDD	72-54-8	15.0	10.0	-	0.30
179.	DDE	72-55-9	7.5	5.0	-	0.15
180.	DDT	50-29-3	15.0	10.0	-	0.30
181.	Dieldrin	60-57-1	7.5	5.0	-	0.15
182.	Endosulfan I	939-98-8	7.5	5.0	-	0.15
183.	Endosulfan II	33213-6-5	7.5	5.0	-	0.15
184.	Endrin	72-20-8	7.5	5.0	-	0.15
185.	Endrin aldehyde	7421-93-4	15.0	10.0	-	0.30
186.	Heptachlor	76-44-8	5.0	5.0	-	0.10
187.	Heptachlor epoxide	1024-57-3	7.5	5.0	-	0.15
188.	Isodrin	465-73-6	7.5	5.0	-	0.15
189.	Kepone	143-50-0	40.0	30.0	-	0.80
190.	Methoxyclor	72-43-5	25.0	15.0	-	0.50
191.	Toxaphene	8001-35-2	1,000	500	-	10.0
	Phenoxyacetic acid herbicides					
192.	2,4-Dichlorophenoxyacetic acid	94-75-7	0.385	0.10	-	2.5
193.	Silvex	93-72-1	0.385	0.10	-	2.5
194.	2,4,5-T	93-76-5	0.385	0.10	-	2.5

Table C-1 (Continued)

BDAT ref. no.	Parameter	CAS no.	Untreated waste (mg/kg)	Treated waste (mg/kg)	Treated waste TCLP (mg/l)	Scrubber water (µg/l)
	Organophosphorous insecticides					
195.	Disulfoton	298-04-4	5,000	0.0335	-	1.00
196.	Famphur	52-85-7	12,500	0.085	-	2.50
197.	Methyl parathion	298-00-0	5,000	0.0335	-	1.00
198.	Parathion	56-38-2	3,750	0.0250	-	0.75
199.	Phorate	298-02-2	2,500	0.0165	-	0.50
	PCBs					
200.	Aroclor 1016	12674-11-2	1,000	500	-	10.0
201.	Aroclor 1221	11104-28-2	1,000	500	-	10.0
202.	Aroclor 1232	11141-16-5	1,000	500	-	10.0
203.	Aroclor 1242	53469-21-9	1,000	500	-	10.0
204.	Aroclor 1248	12672-29-6	1,000	500	-	10.0
205.	Aroclor 1254	11097-69-1	300	250	-	3.00
206.	Aroclor 1260	11096-82-5	400	250	-	4.00
	Dioxins and furans					
207.	Hexachlorodibenzo-p-dioxins		NA	0.15[a]	-	5.6[b]
208.	Hexachlorodibenzofuran		NA	0.87[a]	-	3.7[b]
209.	Pentachlorodibenzo-p-dioxins		NA	0.51[a]	-	2.4[b]
210.	Pentachlorodibenzofuran		NA	0.35[a]	-	2.1[b]
211.	Tetrachlorodibenzo-p-dioxins		0.53[a]	0.39[a]	-	2.6[b]
212.	Tetrachlorodibenzofuran		NA	0.22[a]	-	1.6[b]
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin		-	-	-	-

NL = not on list at the time analysis was performed.

NA = Not detected; however, surrogates not recovered and detection limits cannot be calculated.

- = No analysis performed.

[a] Units are ng/g.

[b] Units are ng/l.

Reference: USEPA 1987. Onsite Engineering Report.

APPENDIX D

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure D-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed into a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

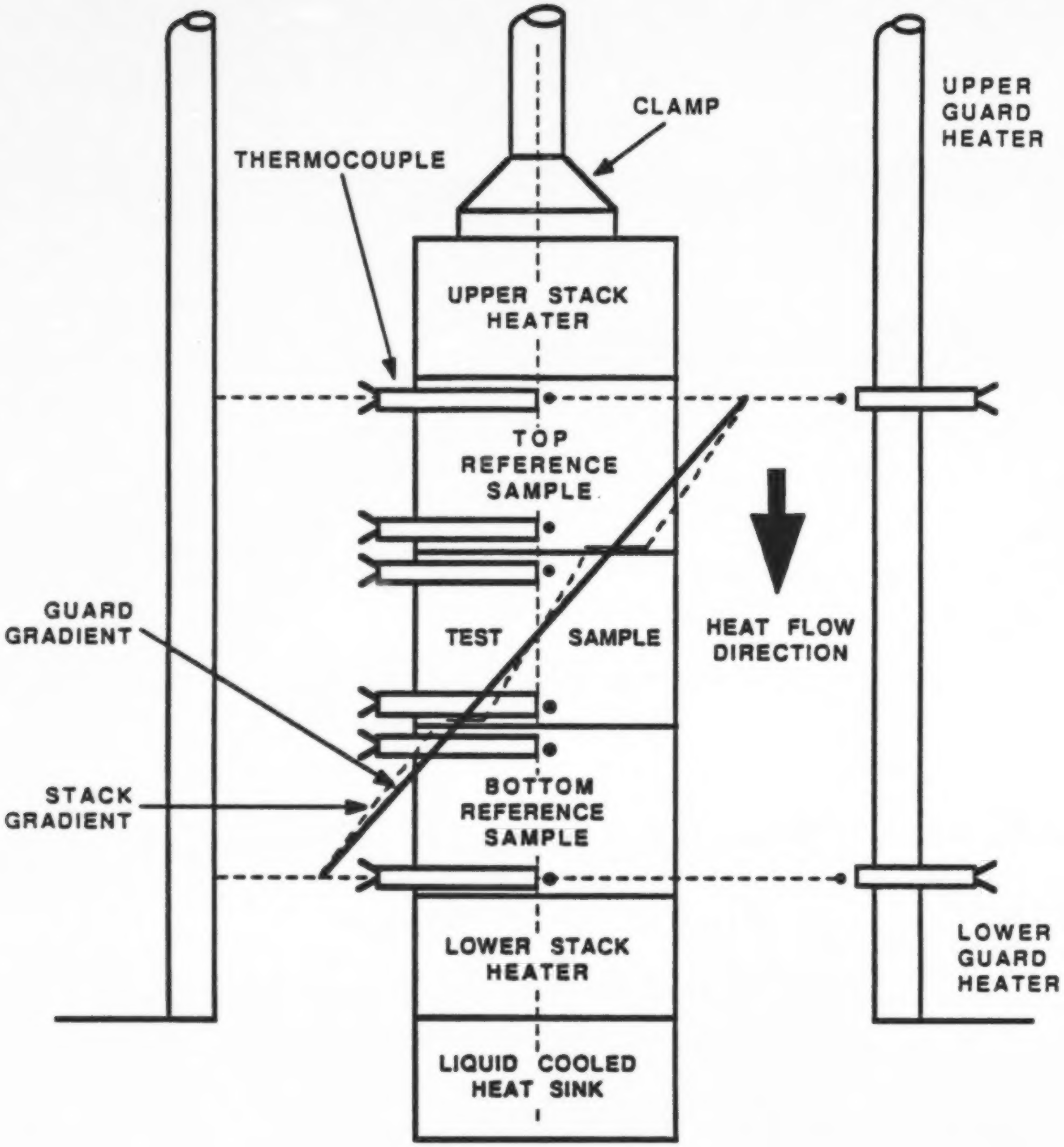

UPPER GUARD HEATER
CLAMP
THERMOCOUPLE
UPPER STACK HEATER
TOP REFERENCE SAMPLE
GUARD GRADIENT
TEST SAMPLE
HEAT FLOW DIRECTION
STACK GRADIENT
BOTTOM REFERENCE SAMPLE
LOWER STACK HEATER
LOWER GUARD HEATER
LIQUID COOLED HEAT SINK

FIGURE D-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The stack is clamped with a reproducible load to ensure intimate contact between the components. To produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack, and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady-state method of measuring thermal conductivity. When equilibrium is reached, the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top}(dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom}(dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference, while bottom refers to the lower reference. If the heat were confined to flow down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2.$$

The sample thermal conductivity is then found from

$$g_{sample} = Q/(dT/dx)_{sample}.$$